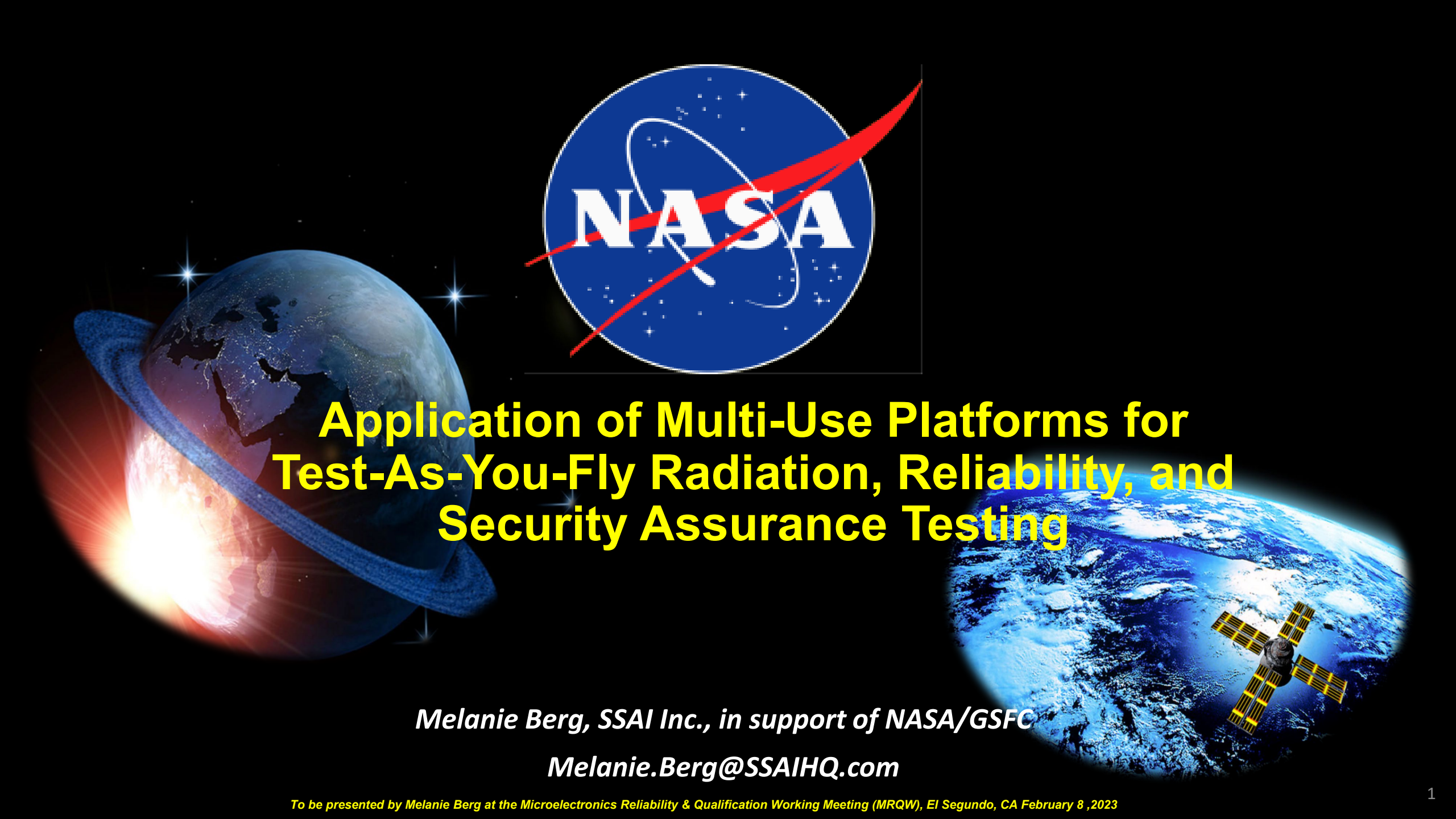


Application of Multi-Use Platforms for Test-As-You-Fly Radiation, Reliability, and Security Assurance Testing

Melanie Berg, SSAI Inc., in support of NASA/GSFC

Melanie.Berg@SSAIHQ.com

To be presented by Melanie Berg at the Microelectronics Reliability & Qualification Working Meeting (MRQW), El Segundo, CA February 8 ,2023

Acronyms

Acronym	Definition
ADC	Analog digital converter
CCD	charged-coupled device
CIA	Confidentiality Integrity Availability
CPCI	Compact Peripheral Component Interconnect
DFF	Flip-flop
DUT	Device under test
EMI	Electromagnetic Interference
GPIO	General purpose input output
I/O	Input Output
ICD	Interface Control Document
LET	Linear Energy Transfer
PCIE	Peripheral Component Interconnect Express
SDR	Software defined radio
SEF	Single Event Failure
SERDES	Serializer deserializer
SGMII	Serial Gigabit Media Independent Interface
SRIO	Serial rapid I/O

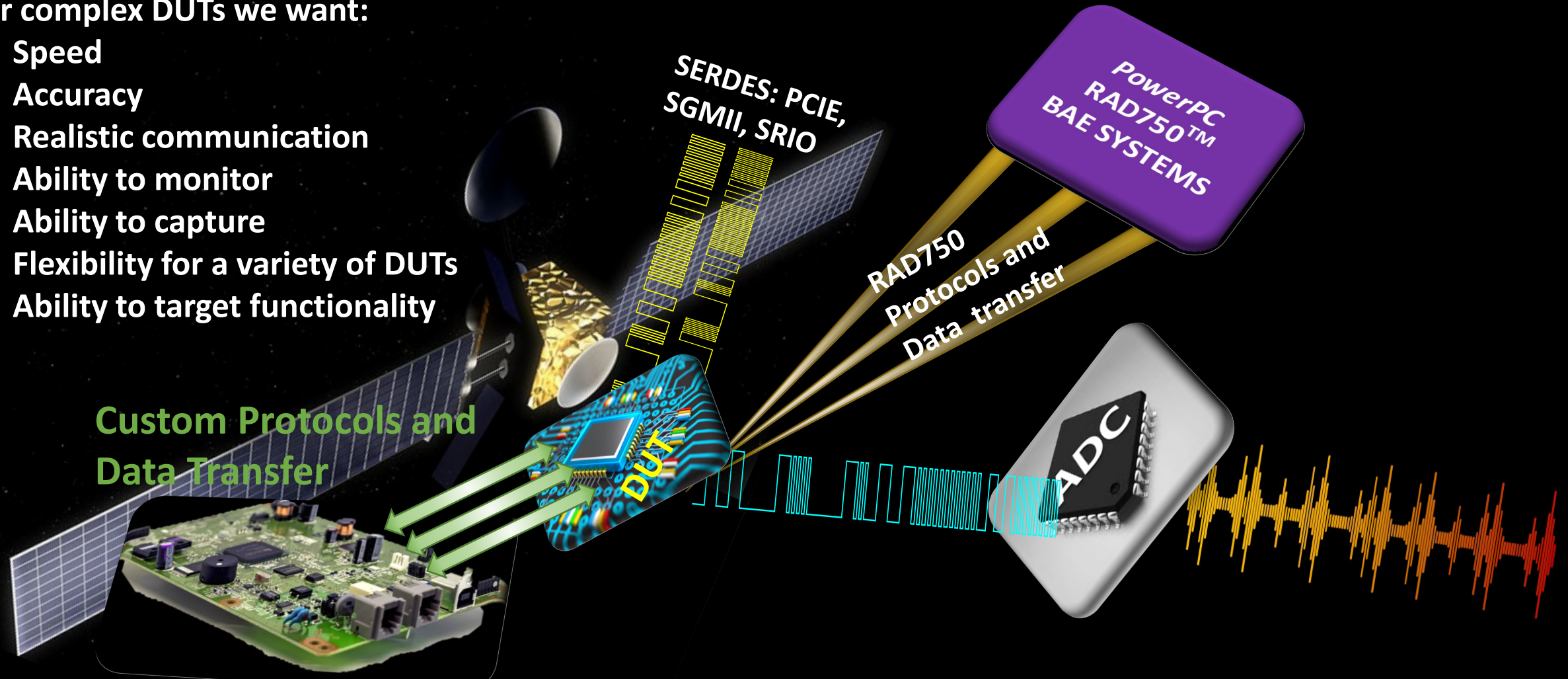
Objective: Test-As-You-Fly

DUT: device under test

Test DUT as if it were operating in its target environment.

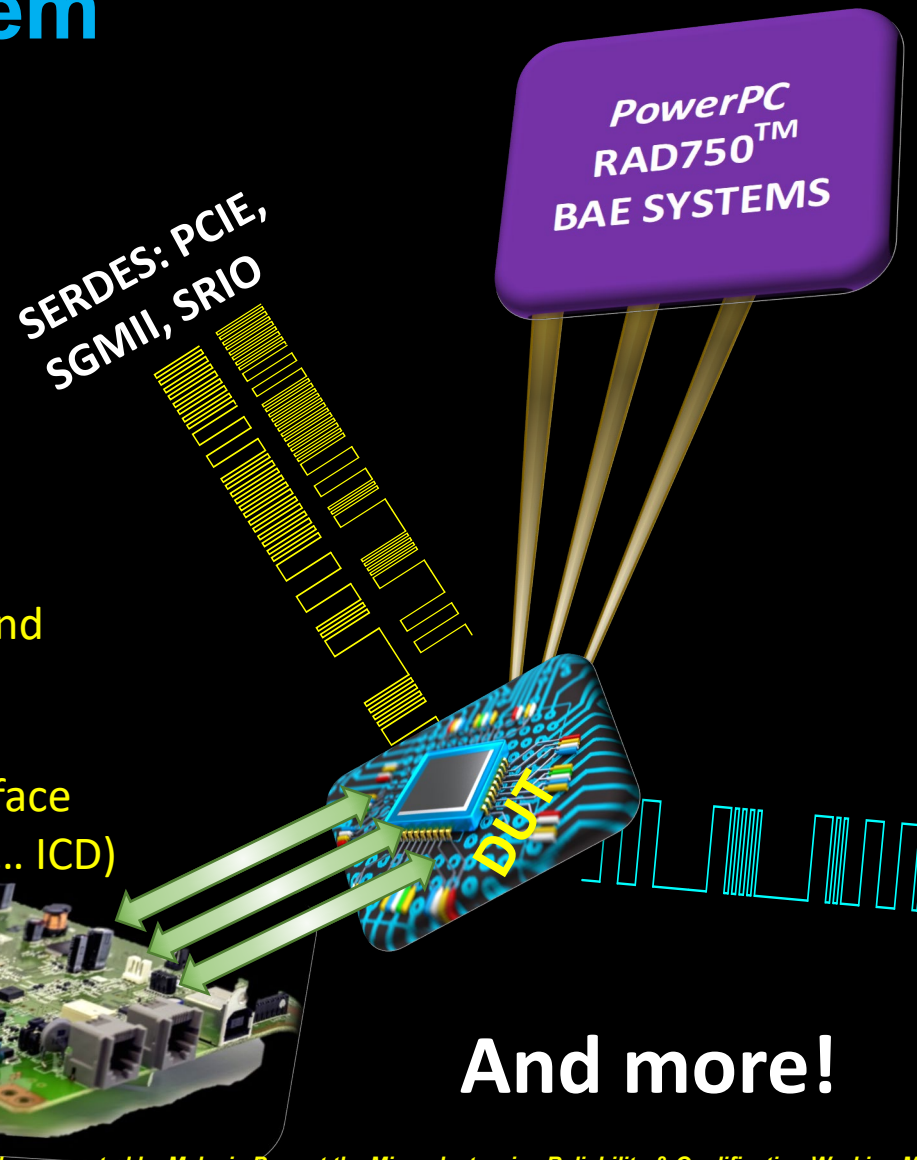
For complex DUTs we want:

- Speed
- Accuracy
- Realistic communication
- Ability to monitor
- Ability to capture
- Flexibility for a variety of DUTs
- Ability to target functionality



Building A Multiuse Platform: Test-As-You-Fly Ecosystem

Customized for mission packet types



- Memory modules: Memory reads/writes
- CPCI Interface
- Data transmission Customized for mission packet types

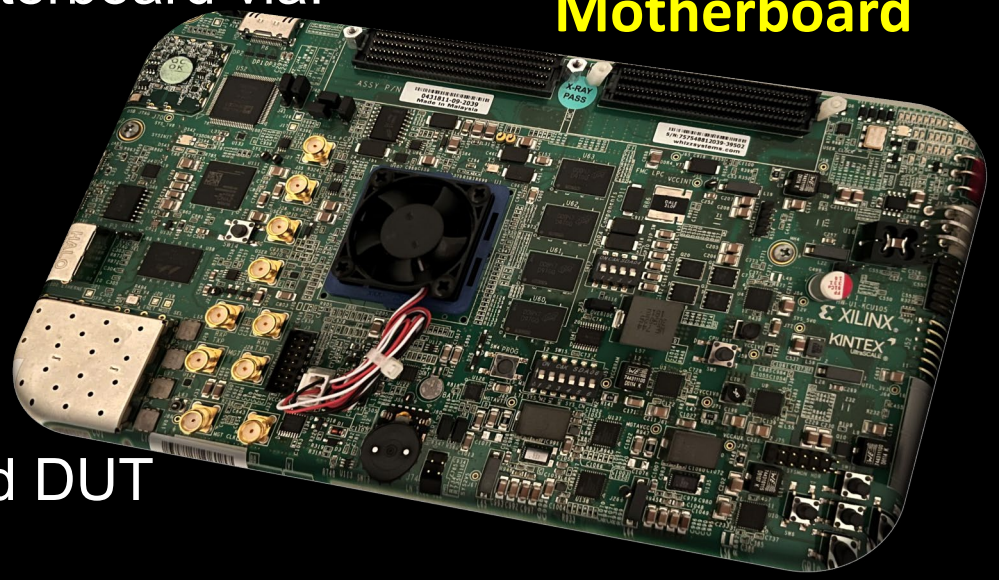
Custom interfaces and controls based on requirements and specifications (Interface control Documents … ICD)

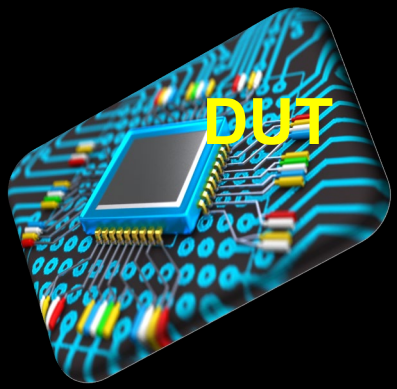
- Software defined radio (SDR)
- CCD Sensors

And more!

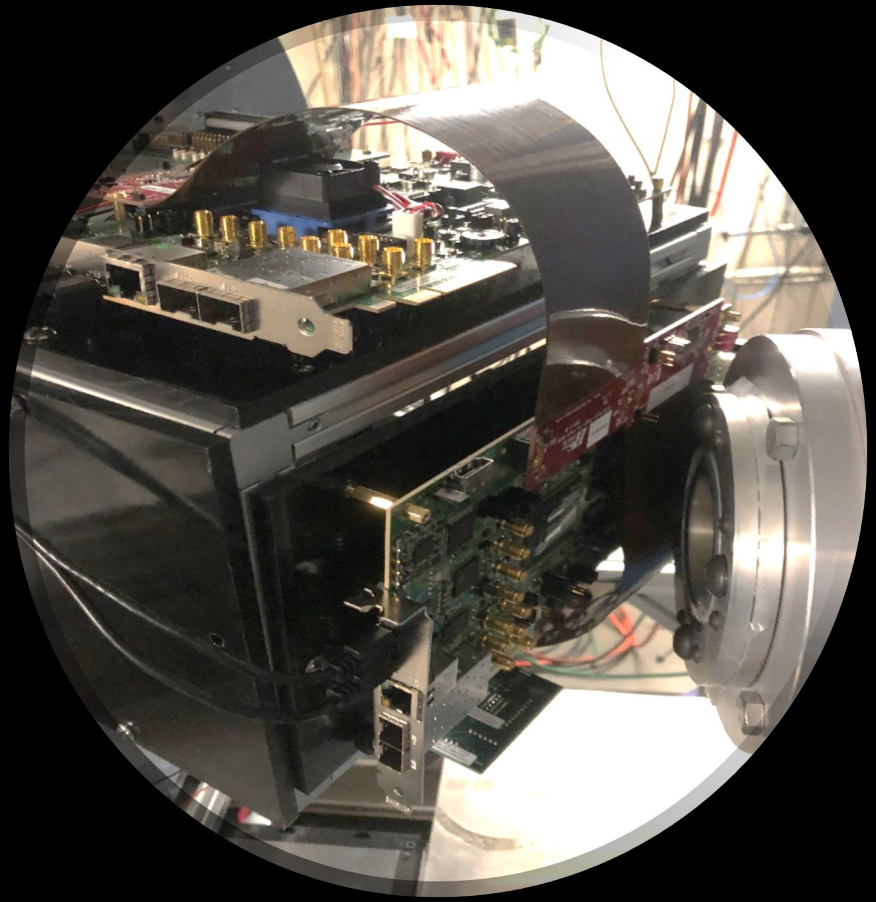
Multiuse Platform: Emulation Library of Spacecraft and Instrument Components

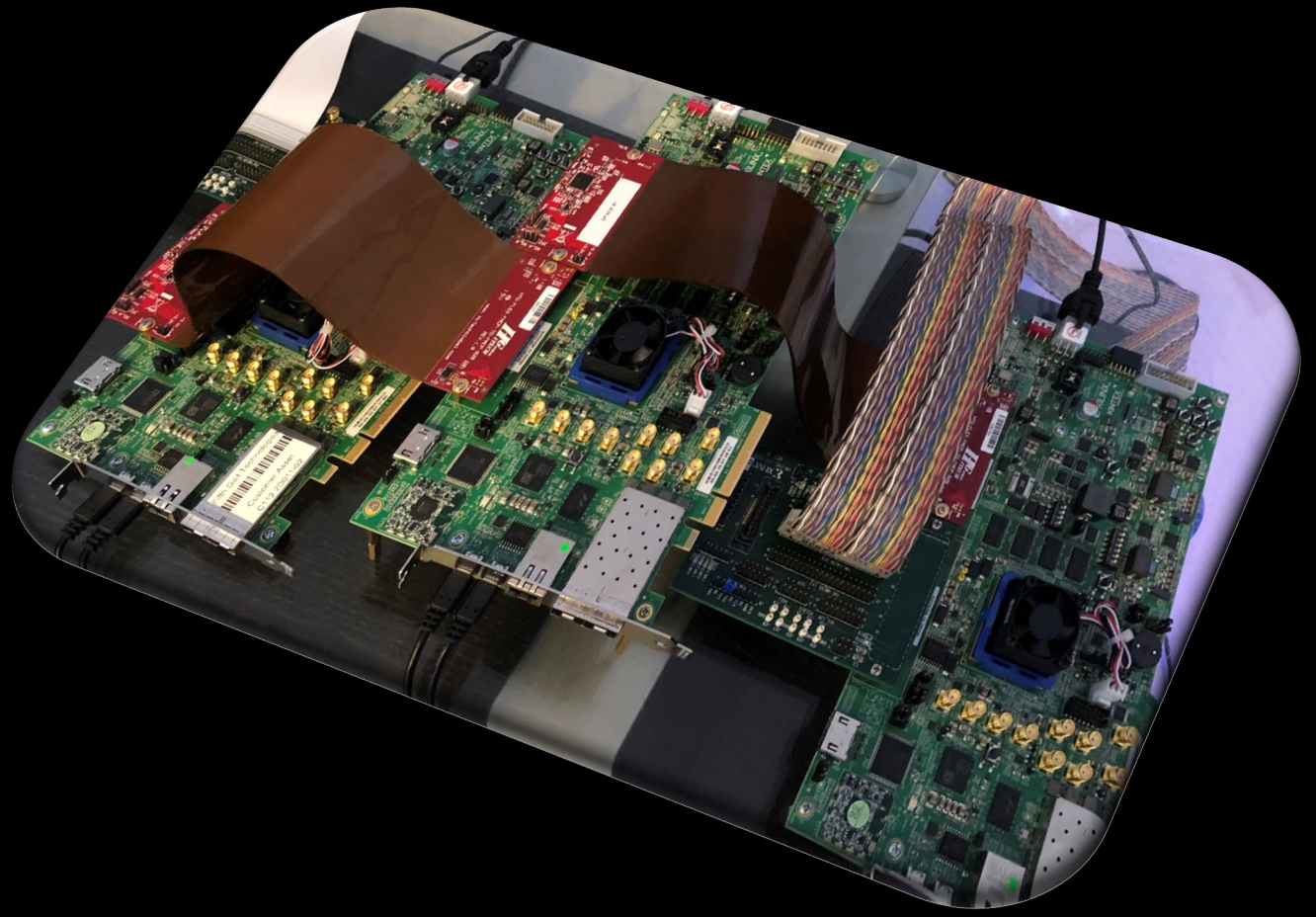
- Many of the DUT peripherals can be emulated inside an FPGA Motherboard.
- Tester board (Motherboard) communicates with Daughterboard via:
  - FMC connectors (that can send the following):
    - SGMII (ethernet)
    - PCIE
    - Highspeed differential I/O
    - Custom protocols
  - GPIO
  - RJ45 (ethernet)
- Realtime (at speed) communication between tester and DUT
  - Tester sends stimuli.
  - DUT responds to stimuli.
- Emulation modules have watch-dogs, checks, and monitors.
- Evaluation boards work well as motherboards.





Multi-Use Platform



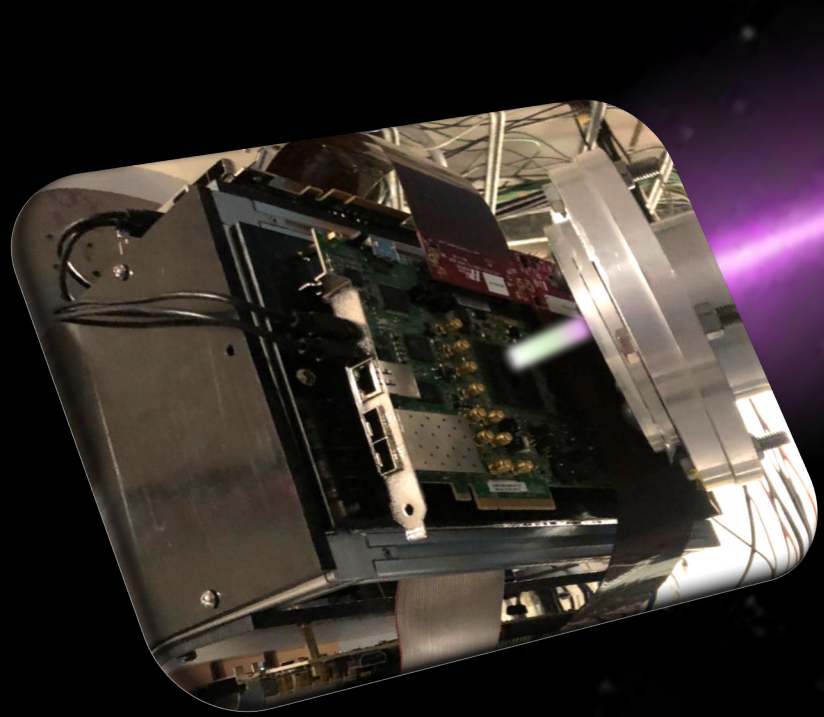


Multiuse-Platform versus Engineering Boards

- **Engineering boards:**
  - Built as less expensive pre-flight boards: Closely represents the flight board.
  - Requires additional equipment to get system level communication.
  - Has limited access to the DUT.
  - Not easy to manipulate.
  - Usually, cannot be used in radiation test environments.
- **Multi-use platform:**
  - **Emulates pre-flight** board components and **other system level communication.**
  - **Does not emulate** the DUT (uses the physical DUT for testing).
  - Tests at the device level – there is direct access to the DUT.
  - Can have more detailed monitors and controls.
  - Can facilitate detailed fault injection (because there are more DUT accessible I/O).

Radiation Testing: Conventional Methods and Test As you Fly

- **Conventional testing:**
  - Usually, much simpler than test-as you-fly and can be performed using the multiuse platform.
  - Modules from the emulation library exist for conventional testing (makes for quick development time).
- **Test-As-You-Fly:**
  - There's no way around it… it's complex.
  - The Multi-use platform emulation library of components helps reduce development time.
  - Design expertise is necessary.
  - Radiation testing expertise is necessary.
  - Successfully used since 2010.



NASA Mission Requiring Multi-use Platform to Obtain Test-As-You-Fly Radiation Data

- DUT: Microchip RTProASIC3
- Requirement: work through worst-week with ground intervention restricted to 1/day.
- DUT area constraints limited mitigation.
- **Error rates** would not make requirements with **upper bound** extrapolation methods.
- **Test-as-you-fly** heavy-ion testing required.
- **Challenging**: Specific DUT circuitry needed to be targeted for test and analysis:
  - Target: critical functionality that must meet requirements.
  - Other functionality is inconsequential

Multi-use Platform with Custom RTProASIC3 Daughterboard

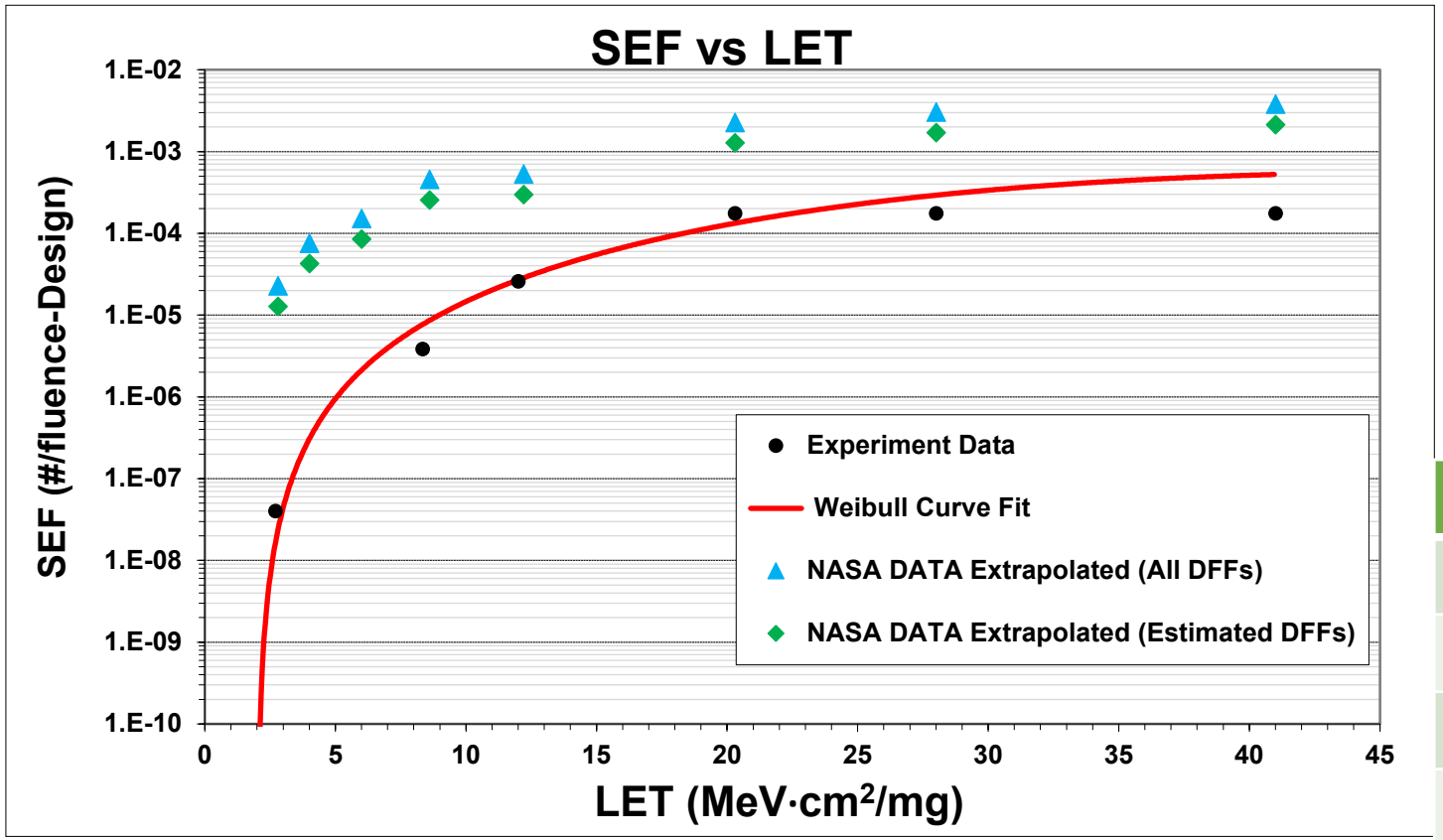
Texas A&M Cyclotron Facility

Test-As-You-Fly versus Extrapolation Data

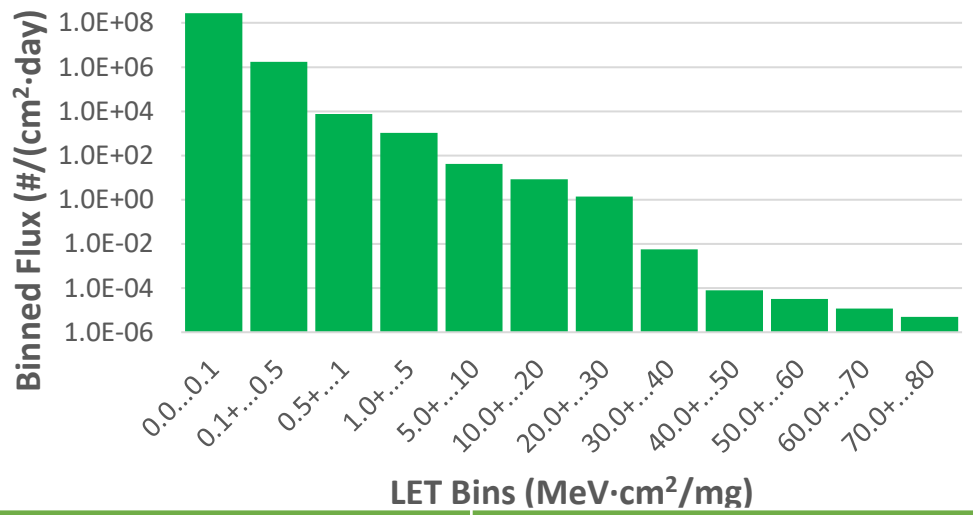
Test-as-you-fly data were able to prove (statistically) mission requirements will be met.

SEF: single event failure

LET: Linear energy transfer



Worst Week 350 mils



LET Range	Fluence/Day
0.1 …0.5	**1.8×10^{6}**
0.5 …1.0	7.6×10^{3}
1.0…5.0	**1.0×10^{3}**
5.0…10.0	**4.2×10^{1}**
10.0…20.0	**8.4×10^{0}**

Reliability and Functional Testing

- Reliability tests performed at the transistor or small circuit level cannot be expected to always extrapolate to the system level.
- Reliability problems have been found late in the design process:
  - Clock signal crossing chip to reach its clock-tree… caused intermittent noise (bad data).
  - Outputs requiring sub-nanosecond resolution having too much jitter.
  - Source synchronous I/O not making timing across temperature.
  - PLL loss of lock during temperature cycling.
  - Fully populated designs having too much internal noise or causing timing to be violated.
  - Power consumption measurements.
- Benefits of the Multi-use Platform
  - Can be used to shake out a variety of DUTs for missions containing strict requirements.
    - Tests can be performed prior to making engineering boards.
    - Temperature cycling and other types of stress tests can be performed at the device level:
      - Ex. Testing source synchronous integrity across temperature and determining the best scheme peripheral type.
    - Device level debug… engineering boards do not let you have enough control and visibility.
- Important to note, the proposed reliability testing is meant to augment NOT to replace.
- Successfully used for the Microchip RTG4 PLL reliability issue. Analysis was able to performed in a more realistic manner for NASA missions.

Trust and Assurance

EMI: electromagnetic interference
CIA: Confidentiality Integrity Assurance

- Trust requires an additional level assurance:
  - The system does all that is required – nothing more and nothing less.
- Testing potential losses to CIA with current platforms lacks coverage.
- Multi-use Platform benefits:
  - Tests the actual DUT.
  - Ability to emulate a bad-actor.
  - Ability to create specialized monitors for fault injection and bad-actor emulation:
    - Back door protection integrity.
    - Signal manipulation vulnerability.
    - Signal output protection.
  - Ability to measure leakage currents and EMI.
  - Direct accessibility to the DUT allows the user to test corner cases (great for integrity and trojan detection).

Questions